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Experimental analysis of strain of blast furnaces shell during the start up to

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Abstract

Circumferential BF hearth shell stress was measured during the two blast furnaces blow-in periods. BF1 had the hearth with not developed salamander. It was blew down after reline and few days of full tuyeres operation. BF3 hearth had fully developed salamander after 12 years of operation. Before start up both BF hearths were identical cleaned up 1 m bellow the tap hole elevation. Blow in line on BF1 also BF3 salamander were circumferential trenched out up to the hearth bottom elevation down. Maximal measured BF1 hearth shell tension level reached

100 MPa. 160 MPa was the detected maximal BF3 hearth shell tension. Tension level 100 MPa was detected 6 days after start up on both furnaces, This level stayed identical on BF1 for the next four days but on BF3 tension rose during the next two days period up to level 160 MPa. Maximal pressure started relieve on both furnaces 8 days after start up. Hearth shell stress stabilized on both furnaces on range 30 – 50 MPa when hearth thermocouples readings started stabilize. Data shows significant contribution of hearth refractory to hearth shell stress creation. Melting rate, tuyeres opening strategy, casting schedule can contribute to BF hearth shell stress control during the blow in period.

Keywords: BF hearth, start up, tension, shell

Nomenclature

σ_{CIR}	circumferential stress increase (MPa)
ΔL_{CIR}	extension in circumferential direction (mm)
ΔL_{RAD}	radial displacement (mm)

1. Introducton

To get real information about hearth shell behaviour during the blow in period, hearth shell tension was measured during two blast furnaces blow-in's. To avoid hearth break out in the future operation was the main intention, Table 1 presents furnaces basic information.

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Table 1. BF1 and BF3 basic data

	BF1	BF3
Working volume m^3	1985	1873
Hearth Ø in m	10	10
Shell Ø in m	12.94	11.99
# of tap hole	2	2
Tap hole angle	180°	87°
Hearth wall refractory	Semi graphite EHM	Semi graphite EHF
Tap hole for start	#1	#2
Hearth shell thickness mm	45	45
Hearth cooling	Hearth staves	Surface
Tuyeres number	22	22

BF1 after reline was emergency shut down 5 days after blow in due to gas cleaning system failure. During the 50 days of unplanned outage a portal was opened above the tap hole #1 to clean up coke and ore from the stack and hearth. Hearth was cleaned up 1 m bellow tap hole elevation and circumferrential old blow in line was trenched out as visible from the figure 1.

Fig. 1 Trenched blow-in line on BF1 up to the hearth bottom.

Gap was filled by coke breeze and new blow-in line was re-build as figures 2, and 3 present.

Fig. 2 BF1 hearth view before coke fill

Fig. 3 View to BF3 trenched salamander

BF3 was blew down and quenched due to planned stack shotcrete outage, plate armor and refractory change. Also portal into the BF3 stack shell above tap hole # 1 was opened to clean up hearth, trench salamander and to build new blow-in line. Two rows of strain gauges were installed on both BF1 and BF3 hearth shells as presented on figure 4 [1], [5]. Each row contained 8 gauges In addition to BF1 four horizontal bars, and one circumferential tape were installed on BF3 hearth.

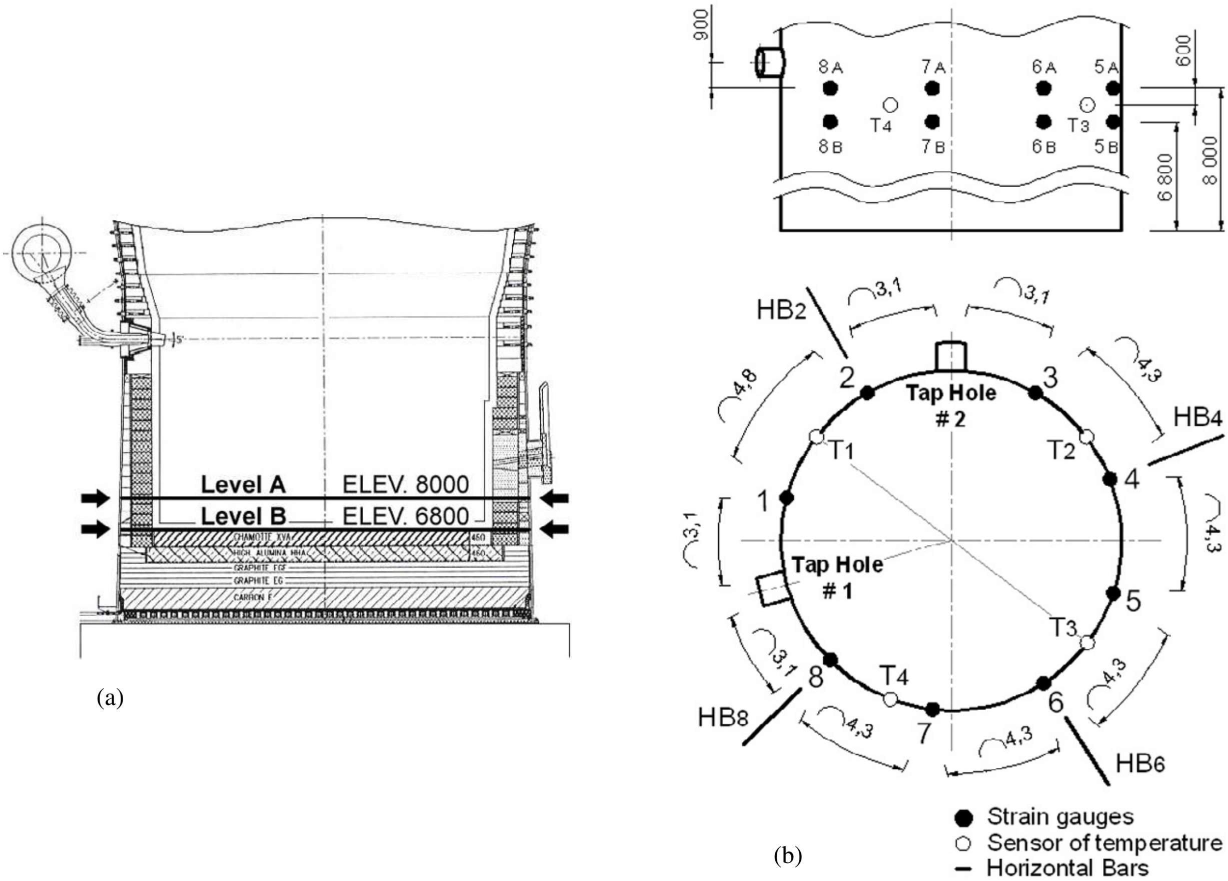

Fig. 4 Two rows of strain gauges installed on both BF1 and BF3 hearth shells - (a) Strain gauges location on BF1 and BF3,   (b) Sensors location on BF3 hearth shell

2. Result and discussion

Before start up both furnaces furnaces were filled with standard blow in burden. Oxygen and natural gas fed tap hole burner was used in first period to heat up hearth and in the next step two tuyeres were opend above tap hole burner to start melting process. BF1 started with tap hole #1 and BF3 started with tap hole #2. On BF1, figure 5 the maximal tension 100 MPa was reached five days after start up.

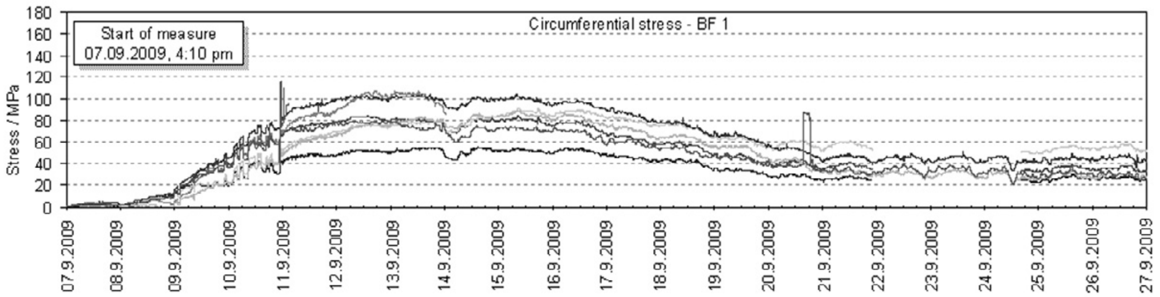

Fig. 5 BF1 heart shell tension development measured by strain gauges

Maximal tension lasted four days and finally 14 days after start up shell tension, became stable on the range 20 – 40 MPa. Not uniform tension distribution through the shell circumference was detected. Maximal tension was measured on the opposite to tap hole #1, which was used for start up. Five hours outage caused approx. 10% BF shell tension drop. Gas and hydrostatic pressure contributed +10% to total stress increase.

On BF3, Figure 6, the hearth shell tension 100 MPa was reached five days after start up. Next two days visible strong raise to maximal level 160 MPa. Maximal tension lasted one day and after next four days dropped to the level 100 MPa and finally after 18 days bellow 60 MPa and after 23 days to the range 30–50MPa.

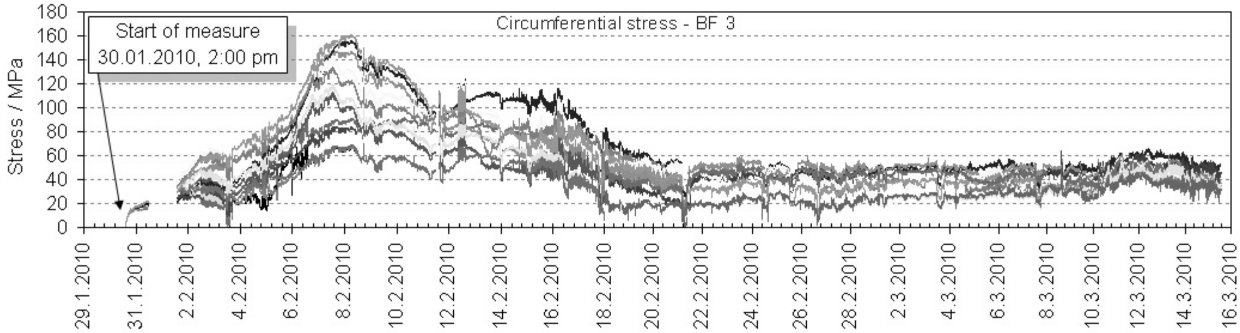

Fig. 6 BF3 hearth shell tension measured by strain gauges

As visible from the figures 6 and 7 also not uniform tension tension distribution was also detected through the shell circumference. Measuring point #6 was on the oposite side to the tap hole #2, which was used for start up. Circumferential tape installed on BF3 hearth shell presented maximal stress 140 MPa.

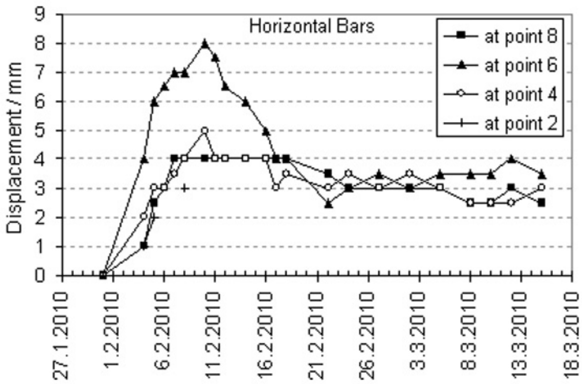

Fig. 7 BF3 horizontal bars displacement during the blow-in period.

3. Conclusions

According to the [2,3,4] the critical values of increments of the circumferential stress, radial displacement and circumferential extension of the blast furnace with diameter 14 000 mm are given in the Table 2.

Table 2 Proposal of critical alarms levels [2]

	I.	II.	III.
σ_{CIR} / MPa	< 165	165 - 220	> 220
ΔL_{CIR} / mm	< 40	40 - 55	> 55
ΔL_{RAD} / mm	< 6	6 - 9	> 9

Table 3 Alarm levels for shell stress, circumferential extension, and radial displacement BF1 and BF3 [5]

		I.	II.	III.
σ_{CIR} / MPa	BF1	< 165	165 - 220	> 220
	BF3	< 165	165 - 220	> 220
ΔL_{CIR} / mm	BF1	< 37	37 - 51	> 51
	BF3	< 34	34 - 47	> 47
ΔL_{RAD} / mm	BF1	< 5,5	5,5 - 8,5	> 8,5
	BF3	< 5	5 - 8	> 8

Legend:

I. - no action is required (acceptable area)

II. - watch very closely, also watch rate of increase

III. - reduce blast volume and blast pressure,casting control

For blast furnace with hearth diameters 12 and 13 m the alarm levels recommendations are presented in the Table 3.

BF3 maximal hearth shell stress was 160 MPa and it is 60 MPa higher than maximal shell stress measured on BF1. They are minimal two differences it should be considered for understanding. BF 1 hearth is cooled by staves, they are located between the shell and hearth refractory and this arrangement could absorb some tension by itself, also salamander in BF1 hearth was not developed, due to five days of operation after reline only. BF3 hearth shell is cooled by showering water straight on the hearth shell surface. That means refractory has direct contact with the shell and internal stress could create stronger shell tension if compare to BF1 hearth. Also BF3 hearth salamander was fully developed during the 12 years of operation.

According to the [2,3,4], the analyses made clear that measured strains could not have been caused by the expansion of the salamander, simply because the salamander expansion will not be stopped by the relatively thin shell, but will crack it. The observed strain was caused by the expansion of the refractory. Comparison of hearth tension results on BF1 without developped salamander and BF3 with regular salamander supporting this statement.

According [2], the strain in the shell reduces when the temperature of the refractory reaches its creep temperature. On BF1 and BF3 stress relieved when hearth thermocouples installed in carbon ceramic started stabilize readings.

According [2], the interesting operational observation is that while the original thoughts about the mechanism were not correct, the method applied seems to be sound: namely concentration of the heat input. This heats part of the refractory hoop more rapidly The locally heated refractory reaches the creep temperature more quickly while the major part of the refractory hoop expands less quickly. When the creep temperature is reached, the thermal expansion of the refractory hoop is partly absorbed by the 'soft' zone and the pressure exerted on the shell by the refractory is minimised. From this point of view the safe blow-in strategy to minimize hearth tension should include the speed of tuyeres openings. It could play significant role together with casting and melting rate strategy. Hearth thermocouples readings special in primary working area could be the source of information that refractory in working area reached its creep temperature be able absorb stress. This direction will be part of future tests.

Phenomena that hearth refractory is main contributor to create hearth shell tension during the blow-in should play significant role to create the recovery plans for blast furnaces after long term unexpected shut downs also. Intention will be not only minimize the hearth shell tension but also avoid or minimize the possible the cracks generation in hearth carbon block before reach greep temperature.

Acknowledgements

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